J/Ψ, $\Psi(2S)$ Production in pp Collisions at E=510 GeV

Leonard S. Kisslinger[1]
Department of Physics, Carnegie Mellon University, Pittsburgh PA 15213 USA.
Debasish Das[2,3]
Saha Institute of Nuclear Physics,1/AF, Bidhan Nagar, Kolkata 700064, INDIA.

PACS Indices:12.38.Aw,13.60.Le,14.40.Lb,14.40Nd

Abstract

This brief report is an extension of studies of $J/\Psi, \Psi(2S)$ production in pp collisions at the BNL with E=$\sqrt{s}$=200 GeV to E=510 GeV at PHENIX.

1) kissling@andrew.cmu.edu 2)dev.deba@gmail.com; 3) debasish.das@saha.ac.in

1 Differential Rapidity Cross Sections for $J/\Psi, \Psi(2S)$ Production at E= 510 GeV

In the present work we use the theory described in detail in Ref[1] with applications to BNL-RHIC, LHC, and Fermilab, based on the octet model[2, 3, 4] for pp production of heavy quark states; and used for studies of pp collisions for Upsilon production at forward rapidities[5], and for heavy quark production at 7 TeV[6] and 8 TeV[7]. This calculation is motivated by the report of preliminary data for $J/\Psi, \Psi(2S)$ production via pp collisions at 510 GeV by the PHENIX Collaboration[8].

For helicity λ=0, the differential rapidity cross section is given by[1]

$$\frac{d\sigma_{pp\to\Phi(\lambda=0)}}{dy} = A_\Phi \frac{1}{x(y)} f_g(x(y),2m) f_g(a/x(y),2m) \frac{dx}{dy} , \quad (1)$$

with with $a = 4m^2/s = 3.46\times10^{-5}$, $s = E^2$, $E = 510$ GeV, $m = 1.5$ GeV (for charm quark), and[1] $A_\Phi = \frac{5\pi^3\alpha_s^2}{288 m^3 s} < O_8^\Phi(^1S_0) > = 3.1\times10^{-4}$ nb. $x(y)$ and $\frac{dx}{dy}$ are given by (there was a typo in the the numerator of $\frac{dx(y)}{dy}$, with $(\exp y - \exp(-y)) \to (\exp y + \exp(-y))$ in Ref[1])

$$x(y) = 0.5\left[\frac{m}{510}(\exp y - \exp(-y)) + \sqrt{(\frac{m}{510}(\exp y - \exp(-y)))^2 + 4a}\right]$$
$$\frac{dx(y)}{dy} = \frac{m}{1020}(\exp y + \exp(-y))\left[1. + \frac{\frac{m}{510}(\exp y - \exp(-y))}{\sqrt{(\frac{m}{510}(\exp y - \exp(-y)))^2 + 4a}}\right] . \quad (2)$$

The gluonic distribution function $f_g(x)$, for $\sqrt{s}$=E=510 GeV[1], is

$$f_g(x) \simeq 1334.21 - 67056.5x + 887962.0x^2 . \quad (3)$$

From Eqs(1,2,3) the differential rapidity cross sections for J/Ψ, $\Psi(2S)$ production via 510 GeV p-p collisions with the standard and mixed hybrid theories[9] are shown in the figure below.

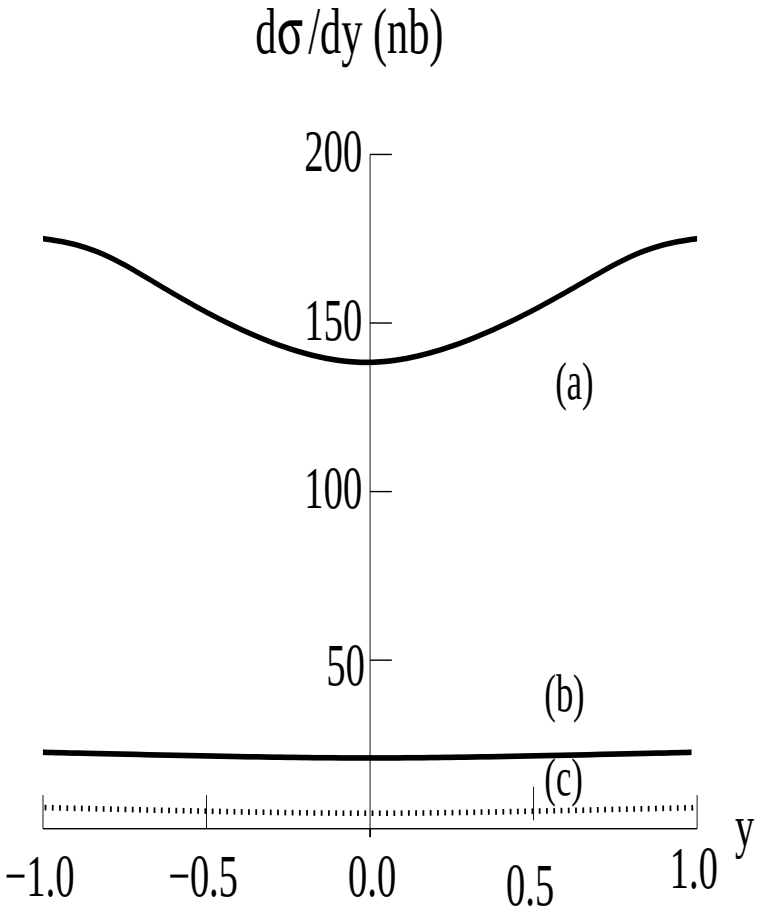

Figure 1: $d\sigma$/dy for E=510 GeV p-p collisions with $\lambda = 0$ producing (a)J/Ψ, (b) $\Psi(2S)$ with mixed hybrid theory, and (c) $\Psi(2S)$ with standard $c\bar{c}$ model.

2 Conclusion

In anticipation of results from the PHENIX Collaboration[8] (also see Ref[10] for recent pp production of J/Ψ and the $(J/\Psi)/\Psi(2S)$ ratio at E=500 GeV) we have calculated the differential cross sections for pp collisions at 510 GeV for J/Ψ production and $\Psi(2S)$ production both with the standard $|c\bar{c}(2S)>$ model and the mixed heavy quark state hybrid theory[9]. As shown in the figure, the cross section for $\Psi(2S)$ production is 0.039 times that for J/Ψ production in the standard model, while in the mixed hybrid theory the factor is 0.122, approximately a factor of π larger, which has been found in experiments at 200GeV[1].

Acknowledgements

Author D.D. acknowledges the facilities of Saha Institute of Nuclear Physics, Kolkata, India. Author L.S.K. acknowledges support from the P25 group at Los Alamos National laboratory. The authors thank Dr. Matthew Durham for helpful discussions. .

References

[1] L.S. Kisslinger, M.X. Liu, and P. McGaughey, Phys. Rev. **D 84**, 114020 (2011).

[2] P.L Cho and A.K. Leibovich, Phys. Rev. **D 53**, 150 (1996)

[3] E. Braaten and Y-Q Chen, Phys. Rev. **D 54**, 3216 (1996)

[4] E. Braaten and S. Fleming, Phys. Rev. Lett. **74**, 3327 (1995)

[5] Leonard S. Kisslinger and Debasish Das, Mod. Phys. Lett A **28**, 1350067 (2013)

[6] Leonard S. Kisslinger and Debasish Das, Mod. Phys. Lett A **28**, 1350120 (2013)

[7] Leonard S. Kisslinger and Debasish Das, Mod. Phys. Lett A **29**, 1450082 (2014)

[8] J. Matthew Durham, PHENIX Collaboration, ScienceDirect, Nuc.Phys. **A 00**, 1 (2014)

[9] L.S. Kisslinger, Phys. Rev. **D 79**, 114026 (2009)

[10] Wangmei Zha (STAR Collaboration), ScienceDirect, to be published in Nucl.Phys A (2014)